U.S. Department of Energy

U.S. Department of Energy
Federal Energy Technology Center

Next Generation Gas Turbine Power Systems

Strategic Visioning Workshop

WORKSHOP SUMMARY

Barton Creek Conference Center
Austin, TX
February 9-10, 1999

Co-hosted by:

Energetics, Incorporated
Columbia, MD

South Carolina Institute
for Energy Studies
Clemson, SC

Next Generation Gas Turbine Power Systems
Strategic Visioning Workshop

WORKSHOP SUMMARY

OVERVIEW

On February 9-10, 1999, a workshop on Strategic Vision for Next Generation Gas Turbine Power Systems was hosted by the DOE Federal Energy Technology Center (FETC). The workshop convened over 45 representatives from stakeholder groups, with almost half representing end-users. The purpose of the workshop was to collaboratively address several questions:

- What are the drivers that will shape the market and technology-selection decisions?
- What are system goals to meet the challenge?
- What are the barriers to achieving these goals?

The workshop was a 1½ day facilitated meeting held at the Barton Creek Conference Center in Austin, Texas. The workshop brought together senior managers and respected experts from various segments of the turbine community to develop a vision that describes a desired future for next generation turbine systems. Participants represented a cross-section of companies that manufacture turbine equipment and components, industrial and utility customers, state and regional energy groups, industry trade and research organizations, and government research managers. The workshop focused on future market and user requirements and the strategies for overcoming major technology challenges. In particular, customers and users of power systems articulated their future power needs and the factors that will influence their decision to use advanced turbine systems. As shown in Figure 1, the Austin workshop and subsequent R&D workshops—for aero/heat transfer, combustion, and materials—are part of a series of workshops that will provide technical and planning input to ongoing DOE program planning.

BACKGROUND

Over the past seven years, DOE has partnered with industry, utilities, and the academic community to conduct the Advanced Turbine Systems (ATS) Program. This program is focused on developing ultra-high efficiency gas turbine power systems that have low emissions, lower electricity costs, and better reliability compared to currently offered products. Specific program goals include:

- 60% system efficiency for utility applications,
- 15 percent point efficiency improvement for industrial applications,
- 10% lower cost of electricity, and
- <10 ppm NO_x emission

Gas turbine manufacturers' products are currently being assembled and tested for precommercial demonstration. The ATS Program is scheduled to be complete by 2001.

Although the ATS has been a proven success, new challenges lie ahead for power producers, state governments, electricity customers, and equipment manufacturers. Environmental compliance and new regulations will continue to become more stringent as cities and regions expect better air quality. Concerns over climate change will put additional pressure on governments and industries to reduce emissions of greenhouse gases. The new dynamics of restructured power markets have caused producers, industry, ,and customers to rethink their product strategy and power choices.

As the turbine community moves into the 21st century, it will be important to understand how changes in markets, regulations, technology, business, and government policies will shape the demand for new and replacement gas turbine power systems. How will utility customers respond to uncertainty in restructured markets? How important will environmental issues be in technology and system selection? How will changes in energy prices affect capacity additions? To what extent will climate change policies influence system choices? Questions like these will need to be explored before the technology requirements and pathways are defined for next generation turbine power systems.

The focus of the workshop was on fossil-based gas turbine power systems greater than 30 MW in size. It did not include microturbine or fuel cell/turbine hybrid systems. It covered a wide range of gas turbine system needs, irrespective of which organizations fund subsequent technology research and development. Some research may be best pursued by equipment manufacturers, some is appropriate for industry collaborations with universities, and some is best suited for industry-government partnerships.

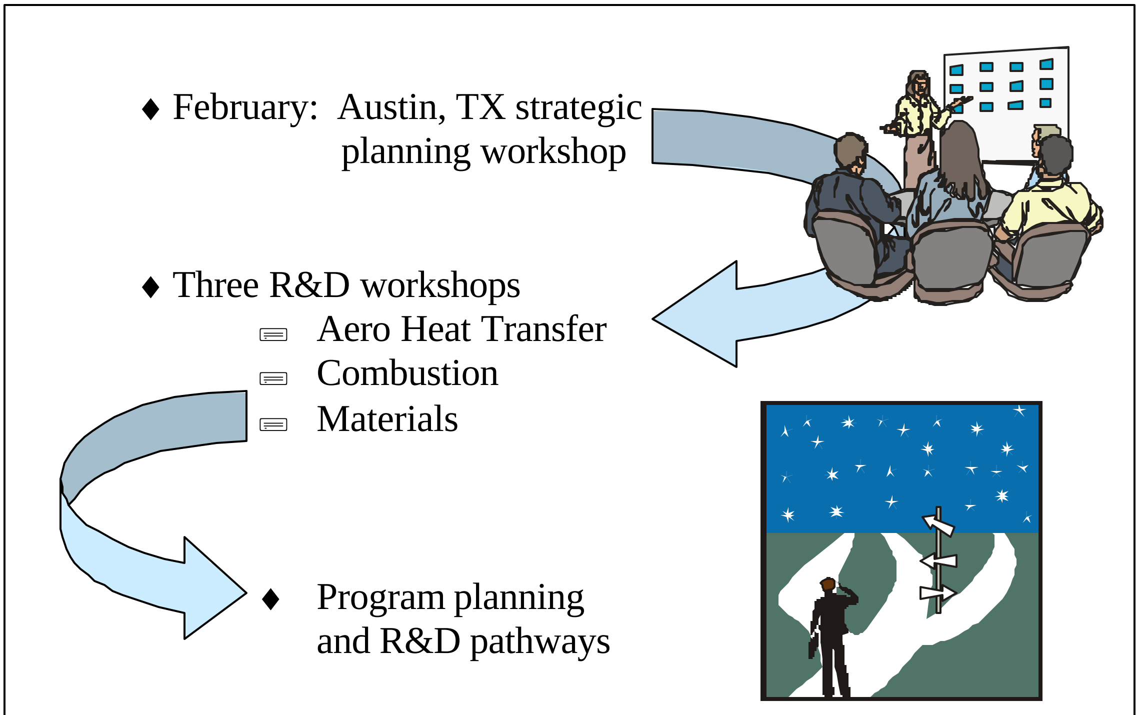

Figure 1: Collaborative Planning Process

Based on the workshop presentations and workshop products presented here, general observations and insights from the workshop include the following:

- Consistent government energy and environmental policy is required to identify and support public-benefits goals, and to clearly link advanced technology options to meeting these goals. A more unified government perspective (i.e., DOE, DOD, NASA, and DOC) is needed to link the strategic vision with practical applications.

- In the near-term, deregulation and market uncertainty is, and is expected to continue to be, the dominant factor in systems and technology selection by end-users.

- Without well-defined public benefits goals and incentives, least-cost, least-risk options (e.g., life extension of steam plants) will prevail.

- The increasing complexity of advanced systems is out of step with the deregulated reality of streamlined resources (e.g., fewer personnel per unit of electricity generated). Public-benefits requirements for improved efficiency and lower emissions increase system complexity while market demands reduce available resources.

- The risk associated with first use of new technology is too high for most users, specifically including their financiers and insurers.

- End users have a broad range of requirements; many of the common denominators are non-technical.

Overall, participants expressed that there is a clear and significant market potential for the advanced flexible gas turbine. Both the 30-150 MW system size and the system flexibility targets are excellent fits with emerging market needs. Flexibility attributes – for various load conditions, for turndown efficiency, and for meeting varied regional, state and local regulatory requirements – are particularly critical. Also, from the user's perspective, market acceptance will be contingent upon the system's operating integrity. Improved reliability, availability, maintainability, and durability are critical in a deregulated market.

While there was general agreement that the technical goals could be met, doing so at an acceptable cost is a significant technical challenge. In particular, balancing combustion efficiency with NO_x production will require new approaches. Moreover, in a deregulated market with no large utility organization able to support first use, new risk-sharing approaches and mechanisms will be needed.

PLENARY SESSION: PRESENTATIONS AND PERSPECTIVES

The plenary session on the morning of the first day convened with opening and welcome remarks from Rita Bajura, DOE-FETC Director. This was followed by presentations on government, end-user, and industry perspectives on the need for and future directories of next-generation turbine systems.

Rita Bajura, *Director, DOE-FETC*, discussed the changes in markets, environmental needs, and other drivers that pose a much-different challenge than when the original ATS program was defined eight years ago. Major trends that a next generation of systems must address are:

- Recognition that global climate change is a significant environmental issue, for which the technological options are improved efficiency, the use of low-carbon fuels, and carbon sequestration
- Continued pressure on environmental protection at the local and regional level, and the attendant economic incentive to replace older coal-fired units
- Deregulation and restructuring of the energy industry, which has led to less interest on the part of utilities to invest in "public benefit" RD&D
- Continued pressure for a smaller government role, with a strong emphasis on measurable public benefits and a role which the private sector would not play or would do so at a much slower pace.

In the workshop deliberations, the appropriate context is the broader world of a restructured industry 10 or more years from today. While these structural and market trends present formidable challenges, the large size of the potential markets make a next-generation gas-turbine program a highly important opportunity for collaboration.

Abbie Layne, *ATS Product Manager, DOE-FETC,* presented the DOE perspective on developing a nationwide partnership for next-generation systems. This included the rationale for the program public benefits and the appropriate federal role as supported by the President's Committee of Advisors on Science and Technology Policy (PCAST) and the National Energy Strategy. The DOE-FETC vision for next-generation gas turbine power systems is:

- The cleanest, most efficient, cost-effective, fuel-flexible, and reliable gas turbine power system available
- Systems not benefiting from the ATS program (i.e., flexible 30-150 MW systems)
- Government support to develop systems will result in significant U.S. economic and public benefit
- Collaborative development with the strength of U.S. technology partnerships of industry, universities, labs, and institutes.

The expected outcome of the workshop is input for a collaboratively-developed "roadmap" of the program—and the collaborative opportunities to make it succeed.

Mike Osborne, *Naval Sea Systems Command*, described the U.S. Navy inventory, technology characteristics, and strategy for gas-turbine use in ships and crafts. Gas-turbines are used for both propulsion and power generation in a variety of current applications, while intercooled recuperative gas turbines and integrated power systems are the current development focus. The Navy policy and strategy for new ship procurement and deployment is now performance based, with industry deciding how best to meet Navy objectives. Importantly, the ability to meet or exceed environmental requirements complements existing program goals for improved readiness and effectiveness and for lower cost of ownership. Employing this new strategy, four separate next millennium (2006) ship programs may have advanced gas turbines.

John B. Lovelace, *Arizona Public Service Company,* presented users' perspectives on next-generation systems, and on the challenge of managing power-generation resources in an era of heightened competition and scarce resources. This included a user's "wish list" – easy to permit, low investment cost, high efficiency, high reliability and availability, good operating characteristics, and low maintenance costs – and the related user concerns about permitting, reliability, operations, maintenance, and cost factors under real-world conditions. User recommendations for next generation systems are:

- Provide continuous monitoring of hot components
- Develop repair procedures for parts
- Develop remaining life NDE techniques
- Develop clear and reasonable emission regulations
- Follow development through maturity
- Maintain interface with users.

Steve Gehl, *Director, Strategic Technology and Alliances, EPRI,* presented the EPRI perspective on the transition from an electric utility business to an electricity enterprise with a wide range of products in addition to power. Within this framework, the primary opportunities in a developing gas turbine market are for the replacement/displacement of existing base-load plants, mid-range flexible units, and new products for new customer needs, such as small distributed generation units and maintaining power quality. The overall opportunity for gas turbines reflects the following:

- World energy needs will at least double within 50 years
- Resource availability will not be a major constraint
- Gas turbines firing natural gas will be a fixture of world energy supply structure for decades
- Growing gas turbine use in clean coal and advanced nuclear applications
- Efficiency and flexibility improvements are critical to gas-turbine role in a carbon-constrained future.

David Walls, *Arthur D. Little,* presented a strategic evaluation of RD&D needs and opportunities for U.S. mid-sized gas turbines in intermediate load applications. Performed for DOE and the California Energy Commission, the assessment examined six broad classes of applications under a range of scenarios. Preliminary results conclude that the adoption of advanced mid-size gas turbines will lead to significant public benefits and that the cumulative energy and emissions savings could be substantial, especially in later years if the technology becomes widely adopted. The assessment concludes that there is a significant market potential and associated public benefits if the aggressive performance goals (50% LHV efficiency at capital cost of $250/kW) are met.

Harvey Goldstein, *Parsons Power,* presented an industrial perspective on the market needs for flexible systems. Building on the success of ATS, changing market now demand even more:

- The capital and operations and maintenance (O&M) costs of a frame machine
- The efficiency and maneuver capability of an aero machine
- Reliability, flexibility, and "finance-ability"

There is a significant market potential in two areas of repowering of steam electric plants: coal-fired units can benefit from feedwater preheat repowering and gas/oil fired units can benefit from boiler replacement repowering.

Lee Langston, *International Gas Turbine Institute,* presented IGTI/university perspectives on flexible mid-size systems and the associated R&D needs. The proposed program makes sense from the standpoint of both the markets and the technology. Research needs include combustion, gas path 3-D flows, unconventional turbine cooling, engine diagnosis, and ceramics. Associated development needs are a third-party certifier (an FAA for electric power gas turbines) and basic engineering education. The proposed next-generation program should be the next step, with a university research component in the critical R&D areas.

William H. Day, *Pratt & Whitney, representing the Gas Turbine Association*, presented industry perspectives on the future directions for next-generation systems. Accomplishing the program objectives will provide the following:

- Market and U.S. Economy
  - Reduce life-cycle costs for the diverse set of power plants that will be added in a deregulated environment
  - Increase U.S. based suppliers' share in international markets
- Public Benefits
  - Reduction of emissions, e.g., CO_2 and NO_x for new and retrofit equipment
  - Increased electric system reliability
  - Increased choice of competitive generation options
  - Synergy with Vision 21 plants
  - Enabling technologies support other government missions, e.g., defense capability enhancement.

Overall, the program will develop critical technologies that will enhance all types of gas turbines. Flexible systems will complete the spectrum of advanced gas-turbine types to complement those developed by other programs (e.g., microturbines). Building on the success model of the ATS program, the program results will improve costs, reliability, and environmental performance of electric-power generating systems and will complement other government programs to achieve public benefits.

PLENARY SESSION: DRIVERS AND GOALS

In a facilitated session in the afternoon of the first day, workshop participants brainstormed on two questions:

- What are the drivers that will shape the market and the technology-selection decisions?
- What are system goals to meet the challenge?

The group first brainstormed to identify the market and technology-selection drivers. These were then organized by the group into ten major categories:

- Flexibility

- Financing
- Technical system requirements
- Resource availability (to make power to run)
- Low life-cycle cost
- Policy: economic/environmental/social
- Emerging labs (sets boundary of the state-of-the-art for competitive advantage)
- Environmental
- Risk
- Competitive market environment

Table 1 presents the results of this step.

The group then brainstormed on the system goals that would respond to the market and technology drivers. A preliminary set of goals was established. These were then assessed by the group, resulting in the selection of a target goal set for 2010. Table 2 presents the overall goal set and Table 3 presents the selected goals for 2010. The combination of the ten barriers and the 2010 goal set was then used as the starting point for the breakout sessions.

Policy: Economic/ Environmental/ Social	**Emerging Technology** (Sets boundary of the state-of-art for competitive advantage)	**Environmental**	**Risk**	**Competitive Market Environment**
• Certification • Environmental regulation • Political acceptability • Permitting process • Politics • Deregulation • Availability of development funding • Consistent availability of development funding • Congressional whims • Displacement of inefficient steam plant equals replacement of existing generation • Goals/targets • International perception of emissions/markets • International perception of emissions/markets • Grid optimization • Attitude toward collaboration now versus competition later • Resources ($) availability for technology development • Law of unintended consequences • Weighting factors in optimization of numbers	• Technology availability: the state-of-the-art at decision making time • What is not known • Component aerodynamics • Flying engine development; aeroderivative • Assured performance of advanced technology components - "infant mortality" • Multi-disciplinary design • Reduction of internal losses • Incremental improvements to existing cycles • Manufacturers' marriage to process and product they develop does not bring better technology • Perceived development time – time to market • Design to cost • Non-destructive evaluation techniques • Integration of technology into existing portfolio • Novel cycles • Evolution of new financial models • Certification; need capability to measure (state-of-the-art) • Evolution of computational and physical models	• Permitting process • Environmental issues – emissions • Low carbon release • Achieving lowest achievable emission rates • Evolution of a climate change model	• Risk mitigation • Risk management • Liabilities • Mechanisms for risk sharing • Merchant plants • Insurability • Risk of ownership/market	• Multiple applications • Availability of low-cost gas • Customer demand/load demand • Numbers (efficiency, reliability, etc.) • Reputation • Competitive market pressure • Replacement of existing generation • Policy • Age • Environment • Regulations • Market needs • Fuel cost • Fluctuating demand in price for power • Global market; different needs than from U.S. • Enhanced energy marketing strategy; project portfolio synergies • Development of competing technologies • Customer reaction to new technologies; negative reactions • Greater return • Technical complexity • Demand growth • Transmission system operation and planning

Table 1. What are the Drivers That Will Shape the Market and Technology-Selection Decisions?

FLEXIBILITY	FINANCING	TECHNICAL SYSTEM REQUIREMENTS	RESOURCE AVAILABILITY (TO MAKE POWER TO RUN)	LOW LIFE-CYCLE COST
• Operational flexibility • Portability (able to move unit) • Autonomy • System not dependent on separate start system • Self contained • Stand alone • Wide range of size • Flexible performance	• Financial backing • Collaboration between companies • Evolution of new financial models • How to make decisions to buy	• Technology integration • Technology characteristics • Quick implementation time • Zero emissions • Interfaces • Fuel economy • • Fast starting; inherent start capability • Air flow: machine requirement; more air, more structure • Technical complexity • Goals/targets • The efficiency to be achieved • Performance • Fuel treatment to make it useable • Low water consumption • Automation; remote control • High turn-down efficiency • Fuel choices • Permitability • 60% efficiency with no steam • Exhaust temperature • Safety and safe operation	• Vendor manufacturing and delivery time • Manufacturing capacity and human resources • Staffing requirements • Fuel quality • Manufacturer production schedule • Availability of low-cost resources	• Operating cost • Reliability, availability, maintainability, and durability (RAMD) • Repairability of parts • Compressed maintenance schedules • Fast turnaround on vendor-supply parts • Trends in maintenance • Parts availability • Keep on hand • Alternate vendor parts • Improved engine diagnostics • Unit maintainability • Quick change-out of components • Mean-time-to-failure/mean-time-to-repair • Low cost (O&M) • Non-destructive evaluation techniques • Design for repair/overhaul ability • Capital cost of acquisition • Cost of product • Combined cycle bus bar cost • Total cost • Lowest cost • Life-cycle cost

Table 1. What are the Drivers That Will Shape the Market and Technology-Selection Decisions? ***(CONTINUED)***

TURBINE SYSTEM GOALS (ALL)	
• Improved design efficiency • Cost of electricity • Service life • Lifecycle cost • Reduce carbon emissions • Market penetration • Dispatchability flexibility - Economic/energy requirements - Start up • NOx • Reduce O&M cost (non-fuel) - Simple -- Gas turbine alone -- 100 MW - 15-20% below market • Reduce capital cost - No greater than ATS machine - 2010 machine retrofittable at later date - 25% of 2010 market - 400 starts per year • Meet any 2010 requirements • Retrofit capable	• Reduce NOx emissions; eliminate SER? • Handle introduction of new system properly (finish ATS introduction correctly) • Predictable commission time • Methodical • Plan for it • Reduce maintenance without decreasing mean time between removal • Turn down - maintain same efficiency • Upgrade to fit market needs as they evolve - design in anticipation of future need • 2010: maintain ATS achieved level for NO_x • Local regulation • 2010: grams per useful megajoule (meet 2010 standards)

Table 2. What are System Goals to Meet the Challenge?

GOALS TO ACHIEVE . . .	. . . BY 2010
• Improve design efficiency • Cost of electricity • Service life • Reduce carbon emissions • Market penetration • Dispatch flexibility • NOx • Reduce O&M costs • Reduce capital cost	• 45-50% • 15-20% below market • No greater than ATS • Retrofitable • 25% of 2010 market • 400 starts per year • Meet any 2010 requirement • 15% reduction(less than comparable conventional product) $/kWhr • 15% reduction (less than comparable conventional product) $/kW

Table 3. Selected Goals for 2010

BREAKOUT SESSIONS: TECHNOLOGY BARRIERS

On the morning of the second day, the workshop participants separated into three working groups:

- Group 1: Combustion Technology
- Group 2: Materials, Heat Transfer and Aerodynamics
- Group 3: Design, System Integration, and Market Application

Using the 2010 goal set as the target, each group brainstormed on the question:

- What are the barriers to achieving these goals?

After brainstorming, the groups then organized the input and voted on priority topics. Voting was separated by participant category – users versus non-users (manufacturers, suppliers, and R&D performers). Summaries of each group follow.

Group 1: Combustion Technology

Group 1 identified a set of five critical barriers. The overall risk and uncertainty of using new technology is key, especially where system integrity is crucial to users. In particular, the risk in first-use or demonstration applications without appropriate risk-sharing is a potential show-stopper for users. Technically, robust combustion is a critical issue, with turn-down requirements of users being particularly challenging. Regulatory uncertainty related to, for example, local and regional environmental requirements are also a major barrier. Finally, the lack of program "infrastructure," including matching the necessary political will to meet real needs, and the lack of a resulting clear path forward was cited.

Detailed topics from the group include:

- Risk and uncertainty
  - CFD does not answer all problems
    - -- "lower density" risk
- Robust combustion
  - Sensor and engine monitor and control
  - Lack of test capability (public)
  - Need to monitor combustion temperature
- Missing program infrastructure
  - Poor integration of design
  - Manufacturing and service of complex system components
  - No commercial alternatives to supply "peripherals"
- Tunnel vision
  - Looking at engine rather than overall system

Table 4 presents the complete Group 1 results.

Group 2: Materials, Heat Transfer, and Aerodynamics

The group identified four key barriers. As with Group 1, risk mitigation of issues such as durability and service life is critical. Market uncertainty is a prevailing barrier, with clear definition needed of what system the market does or does not want, such as unconventional turbine cycles and specific efficiency needs. Gaining government support was cited, covering Congressional perceptions of the technology need and opportunity—and the attendant funding limitations. Finally, development of enabling technologies such as innovative cooling manufacturing and single-chrystal casting technology was strong cited by both users and non-users.

Detailed topics from the materials group included:

- Required technology development (enabling technology)
  - Computation/Design
    - Maintaining high off design efficiency
    - Behavior of non-engine components in system
    - Assessment of computation and prediction
    - Multidisciplinary optimization
    - Closed-loop cooling
    - Believable complete engine simulation
    - 3-D aerodynamics compression and turbine
    - Innovative internal cooling designs
- Materials
  - Thermal barrier coatings
  - Achieving high design life
- Sensors
  - Advanced diagnostics of turbines components
- Manufacturing
  - Innovative cooling concepts
  - Dimensional tolerances
  - High cost of cooling hardware
  - Manufacturing 3-D aero-compressions and turbine components
- Gaining government support
  - Funding for testing
- Understanding what the market wants in terms of system definition
  - Recuperators and re-heater design
  - More accurate definition of operating flexibility needs
  - Integration with other plant
  - Different cycle component integration
  - Single vs. combined cycle
  - Unconventional turbine cycles
  - Environmental constraints
  - Choice of cooling approach
- Risk mitigation
  - Uncertainty with predictability in (various technical) behavior
  - Lack of 3rd party certifier for new turbine performance and life
  - In situ condition monitoring
  - Behavior of non-engine components within system
  - Use of immature technology

- Lack of OEM component testing

Table 5 presents the complete Group 2 results.

Group 3: Design, System Integration, and Market Application

Group three identified five priority barriers. Market uncertainty was a predominant issue, particularly on the part of the users. With deregulation as a driver, the expected market price for electricity is highly uncertain. Policy goals were considered a major barrier. Specifically, the lack of clear goals or, alternatively, changes in policy and goals over time are a major impediment to the consistent RD&D support that is required. Closely related was the issue of development costs, including the consistent availability of RD&D funding and the availability of launch orders to sustain system introduction into the market. As with Groups 1 and 2, risk aversion, particularly for risk sharing of a first-unit demonstration effort, was cited. Finally, discrete technical barriers, such as the environment requirement for NO_x control to potentially extremely low levels—and at low cost—was cited.

Table 6 presents the complete Group 3 results. Additionally, Group 3 defined a set of possible next steps and initiatives:

- Initiative: National supply efficiency
  - Similar to Combined Heat and Power (CHP) Initiative

- Develop broad program to
  - Identify and build support
  - Provide supporting analysis
  - Provide timeline and public benefits

- Initiative: Incentive for selecting new technology (having longer-term public benefits)
  - Flexible dispatch
  - Intersections with deregulation bodies
  - First-of-a-kind demonstrations

CLOSING SESSION

On the afternoon of the second day, participants reconvened to report-out the results of the breakout groups, discuss common themes, and make final comments. Common themes throughout the workshop include:

- There is a clear and significant market potential for the advanced flexible gas turbine. Both the 30-150 MW system size and the system flexibility are excellent fits with emerging market needs.
- Market timing and market selling price (both for system cost and cost of electricity), however, are highly uncertain due to continuing structural changes in the power sector.
- New-market risk-sharing approaches and mechanisms are critical to new technology demonstration and market acceptance. Deregulation has resulted in the loss of utility “first-use” of systems—with no replacement role in sight.

MISSING PROGRAM INFRASTRUCTURE**	ROBUST COMBUSTION*•	RISK AND UNCERTAINTY *•••	TUNNEL VISION	SYSTEM LEVEL
• Real need ... political will***• • Insufficient number of DOE technical staff • Poor integration of design • (In past) only gas turbine vendors develop (need suppliers) • Manufacturing and service of complex system components • Force-feed single component to meet system • No master plan (right now)*•• • Funds run out in 2001 • Danger to existing product lines • No unified set of goals • No commercial alternatives to supply "peripherals	• Turn-down requirements challenge combustor** • Sensor and engine monitors and controls • Cost • Durability • Lack of test capability (public)* • Performance versus ambient • Need to monitor combustion temperature (not stack temperature) • Higher efficiency hurts NO_x • Standby fuel needs	• Demonstration risk****••• • Regulatory uncertainty*•• • Convince buyer goals will last over engine life•• • Unproven materials for combustor • Risk to adopt new system • Competing distributed generation systems have lower capital risk • Lack of mixture of new and old component and participants • Computational fluid dynamics does not answer all problems • Not having a demonstration site • "Power density" risk • Not having a certification method • Definition of customer acceptance • Tight emissions regulations	• Consumer resistance to "non-cost" goals• • Resistance to (<u>commercial</u>) collaboration• • Looking at engine rather than overall system• • Constrained by past experience • Fear of technical obsolescence • Incremental thinking • Cost of new technology	• Manpower for operation

Table 4. What are the Barriers to Achieving the Goals?
(Group 1: Combustion Technology)

* = Votes by Users • = Votes by Non-Users (Manufacturers, Suppliers, R&D Performers)

REQUIRED TECHNOLOGY DEVELOPMENT (ENABLING TECHNOLOGIES) *****••	GAINING GOVERNMENT SUPPORT*	UNDERSTANDING WHAT THE MARKET WANTS IN TERMS OF SYSTEM DEFINITION **••	RISK MITIGATION **
• Computation/Design • Innovative internal cooling designs • 3-D aero. and compress. and turbine components • Closed loop cooling • Complete engine simulation—believable • Common source of public technological improvements • Central location--clearing house • Multidisciplinary optimization • Computational resources and speed • High cost of cooling hardware* • Assessment of computational predictions* • Validation that code is correct • Experiment measure • Behavior of non-engine components within system: prediction• -- Design validation testing to reduce risk • Maintaining high off design efficiency• • Manufacturing • Innovative cooling manufacturing**•• • Single-crystal casting technology** • Dimensional tolerance* • High cost of cooling hardware* • Ability to repair components • 3-D aero and compressor and turbine components • Joining technologies • Sensors • Non destructive evaluation (NDE)* • Advance diagnostics - turbine component • Material • Thermal barrier coatings**• • Material availability (lack of suitable materials)*•• • Achieving high design life • Low cycle fatigue (LCF)	• Funding constraints** • Funding for testing• • Congressional and staff perceptions* • Politics* • Uncertainty with regulations•	• Choice of cooling approach • Uncertainty as to what is best • Environmental constraints • Lack of integration of plant--solid state conversion system spins faster• • Goals too ambitious* • Unconventional turbine cycles*•••• • Do we or don't we need choice • Single versus combined cycle • Different cycle component integration• • Power generation breakthroughs outside thermal mechanical systems (beyond turbines)• • Integration with other plant• • Unstable market•• • More accurate definition of operating flexibility needs • Local acceptance • Recooperators and reheater design • Predicting market direction* • High life-cycle cost* • Define efficiency needs (load and fuel type)***••	• Uncertainty with predictability in technical behavior*• • Lack of third party certification for new turbine performance/life • Proving efficiency claims for long service life* • Low-cost durability testing* • In situ condition monitoring* • User reluctance to accept new technology* • Behavior of non-engine components within system • In situ measurement for life prediction • Using immature technology • Lack of OEM component testing • End-users• - Everyone else*

Table 5. What are the Barriers to Achieving the Goals?

(Group 2: Materials, Heat Transfer, and Aerodynamics)

* = Votes by Users • = Votes by Non-Users (Manufacturers, Suppliers, R&D Performers)

MARKET UNCERTAINTY • *****	POLICY GOALS ***	RISK AVERSION BY USERS AND FINANCIERS	DEVELOPMENT COST/RISK SHARING (through first unit use)•	TECHNICAL BARRIERS
• Deregulation: owners of generation assets will be different • Market may be broad but shallow (Platte River) • Market risk (Deregulation): when, what, how? • Customer funding/purchasing/ financing capability • Definition of product need in deregulated market • Re: cost of electricity; price of electricity could be depressed due to deregulation • Rapidly changing power generation markets • Power market price signals • Grid/pool stability/reliability • Deregulation – meeting time of day demand • Uncertainty regarding gas availability and deliverability (perception of ...) • Product definition (power, duty, what will it do?) (Beware of the Edsel?) • Pricing based on "energy only" auction (MCP in CA) • Lack of financial incentives/price signals for optimum intermediate operation•	• Lack of national energy use goals****• • Government policy changes - Environmental regulations (EPA) - Funding (DOE) - Justice (Anti-trust) - Commerce (pro-U.S. exports) • Changing government policy over time due to the 4 year presidential election cycle - one administration may start a program; its successor may kill it (examples B-1 Bomber, Clinch River, Super-conductivity Super Collider)• • Lack of a good grid Czar/presence of a bad grid Czar (state/national energy policy) • Corporate welfare concern• • Doing turbine R&D by DOE is often viewed as corporate welfare • Public acceptance of technology versus green power alternatives	• Framework for risk sharing (of first unit)**••• • Technical Risk (Emissions life prediction [duty]) • Risk aversion of developers and power generators requires big investment••• • New product acceptance• • Incentives to trade in steam units • High "hassle factor" in buying and operating generation assets • Low capacity factor unattractive to financiers • Market will not support RD&D • Lack of manufacturers incentives for improvements that reduce their parts/maintenance business	• Development cost (drop in utility (RD&D)• • Development cost (design, test and in-field support) FAA, CAA type certification! Insurance?•• • Development funds*•• • Manufacturer incentives beyond incremental improvements • Launch orders•	• Ceramic materials • Combustion • Technical development in T&D area (storage, superconducting T&D) • Lack of supporting information and data to justify requirements • Vendor manufacturing and design capability/expertise • Environmental requirements** • NOx: Additional removal requirements have non-linear costs

Table 6. What are the Barriers to Achieving the Goals?

(Group 3: Design, System Integration, and Market Application)

* = Votes by Users • = Votes by Non-Users (Manufacturers, Suppliers, R&D Performers)

- There is a strong user requirement for system operating integrity: improved reliability, availability, maintainability, and durability in an era of power competition and constrained resources.
- The general technical challenge is to meet the system goals at acceptable cost. Difficult technical challenges such as balancing combustion efficiency vs. NO_x production will require new approaches.
- Uncertainty in environmental regulatory needs will continue; systems must have the flexibility to meet state, local, and regional requirements of the future.

Closing Remarks and Next Steps

Final comments reinforced many of these general themes. Comments included:

- Need for dramatic change
- Need a collaborative process to put the program in place.
- The program could be a model for other programs
- Each group discussed risk – there are many different kinds – financial, technical, etc.
- There is a diversity of market conditions throughout the country
- Environmental-regulation uncertainty and market uncertainty are key barriers
- A national program is needed
- The key is flexibility, especially for turndown efficiency
- Need to meet "flexible" emission goals in 2010
- Key is flexibility; more important than efficiency in the market segment
- Need to continue to show how this is different form ATS (different market, different system)
- Getting everyone comfortable with trading in the old steam plant for the new gas turbine is a major challenge
- No one here is telling us we cannot do it technically; the problem is to market the program adequately
- Need to continue/expand discussions beyond the technical community
- Coal will remain the #1 fuel source, with efficient steam cycles
- Combustion turbine will not address the overall energy needs of the United States—we need to continue our focus on coal
- Need to keep system options open so that it can be integrated into an IGCC system at a late date
- What will the engine look like? Probably as aero-derivative
- Need flexibility and mechanism to deal with risk aversion
- Need to improve/integrate databases of gas turbine technology in federal program
- Keep the ball rolling—follow-up with more workshops like this one

From its government perspective as a developer and manager of advanced energy programs with demonstrable public benefits, FETC is analyzing the workshop products to help define and plan a next generation turbine program. This includes updating the draft paper, *Developing the Next Generation of Gas Turbine Power Systems - A Nationwide Partnership*, that was provided to workshop participants. As planning materials are developed, they will be distributed to workshop participants for review and comment.

The following specific items are planned:

- Follow-on roadmapping workshops – on aero/heat transfer, combustion, and materials – will address the R&D topics and priorities needed to meet next generation system goals.
- Based on comments that are received and ongoing discussions with stakeholders, FETC will work to identify other follow-on actions, such as collaboration on examining the potential initiatives defined in this workshop. These include the potential of initiatives for improving the national electricity-supply efficiency and incentives for first-use of advanced technology to achieve public benefits in a deregulated power market.

- Follow-up meetings with users will continue and expand the user-focus of this workshop

The workshop adjourned at 2:30 p.m.

If you have questions or comments about planning for this next generation of gas turbine power systems, please contact:

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